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Characterizing solute transport properties for a fractured carbonate aquifer using open-well dilution tests

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Single-well hydrogeophysical approaches have previously been applied to several fractured aquifers in the US and the UK, including karstic carbonate systems, in order to characterise solute transport. These approaches typically use single well hydraulic or tracer tests coupled with image or calliper logs to identify and characterise flowing features. They have variously been used to estimate fracture/conduit aperture and porosity, permeability and/or groundwater velocities, in order to determine groundwater vulnerability or delineate wellhead protection areas. Here, we outline a new workflow for application & analysis of single-well dilution tests for characterisation of fractured and karstic aquifers, and apply this to the Cretaceous Chalk aquifer, Yorkshire, UK.

Chalk aquifers typically have transmissivity that derives essentially from a well-developed network of fractures with solutionally-enhanced apertures and small conduits. Such features can lead to high groundwater velocities and high impacts of contamination on water quality. Knowledge of their solute transport properties is therefore important for delineating source protection areas, characterising contaminant fate and transport, determination of the effectiveness of aquifer remediation, and parameter estimation for models. In this work, single well dilution test data were used to characterise flow patterns in wells and infer properties such as the kinematic fracture porosity, and groundwater velocities. The single-well dilution technique relies on the interpretation of specific electrical conductance (SEC) contrasts between aquifer formation fluid and well fluid column following introduction of saline tracer in the well. Our workflow used both uniform injection (tracer introduced throughout the water column) and point injection (specific depth) tests in open wells under ambient flow conditions. This workflow allowed sections of well showing horizontal versus vertical flow to be distinguished, and the magnitude of such flows and exchanges with the aquifer to be determined. Flow within wells are then used to characterise aquifer properties as follows i) presence and direction of vertical hydraulic gradients ii) relative permeability and depth distribution of flowing features iii) in combination with hydraulic test data (e.g. overall well transmissivity) and geophysical logs, the porosity and permeability of the flowing features at each depth iv) in combination with local hydraulic head measurements in nearby wells, an estimate of groundwater velocities in the surrounding aquifer. We tested predicted fracture porosities and groundwater velocities against those measured in previous studies via large scale pumping tests and ambient flow well-to-well tracer tests. The comparison suggests that the open-well dilution approach can provide reliable flowing porosities and groundwater velocities in fractured aquifer systems.